CROP UTILIZATION AND FATE OF FERTILIZER NITROGEN IN SOIL

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Introduction

In 1972 a research project relating to nitrogen fertilization of stubble crops was initiated with the following objectives:

(1) to evaluate the response in terms of yield of both grain and straw and nitrogen content of stubble seeded annual crops fertilized with urea or ammonium nitrate.

(2) to measure the effect of fertilizer placement on yield of grain and straw relative to both total yield and nitrogen content; fertilizer N, seed placed N, broadcast N, and N sidebanded beside the seed were investigated.

(3) to establish the relative response of urea fertilizer on different soil types of Saskatchewan.

(4) to compare the relative effect of fall and spring applied nitrogen.

(5) to draw a nitrogen balance sheet showing relative uptake of fertilizer N and fertilizer N disposition in the soil after plant growth.

To achieve the above objectives, large scale field plots were conducted. In association with these field plots, microplots consisting of ^{15}N were incorporated at all sites. Fertilizer N cannot be differentiated from soil N under most conditions. A proper evaluation of the relative efficiency of different forms of nitrogen and its disposition in the plant and soil, therefore, requires the use of ^{15}N.

Results

The above objectives required a large well integrated research program. The yearly data are summarized in the Department of Soil Science's Plant Nutrition Research reports. The results from the four years make it possible to draw a number of conclusions.

(1) Field scale plots -- Field scale plots on two sites in 1972 with wheat, barley and rapeseed, a detailed study in 1973 with the same three crops, and an investigation of 6 sites in 1974 indicated that although sidebanding and broadcasting of nitrogen showed some differences from site to site and from crop to crop no consistent difference could be established between placements. Thus three years of detailed field investigations had not indicated the superiority of either sidebanding or broadcasting with either urea or ammonium nitrate fertilizer. Seed placement in the very moist year of 1973 did not show any differences for wheat and barley but high rates of urea resulted in very drastic yield decreases. Seed placement at high rates was generally detrimental.

The comparison of urea and ammonium nitrate in the same trials described earlier for placement, in addition to 10 trials on a diversity of soils in central and eastern Saskatchewan during 1975 did not show a significant difference between urea and ammonium nitrate on most soils. In 1975, fall applied fertilizers, especially nitrate, showed a lower yield response in 5 of the 9 sites which showed responses to fertilizer. Fall applied nitrogen, especially nitrate, showed slightly lower yield responses. An example of the response obtained in the Saskatoon plots is shown in Figure 1. The data for Annaheim (Fig. 2) show lower fall urea-N recoveries for the fertilizer N on the field scale plots on a soil that had a higher available N content.

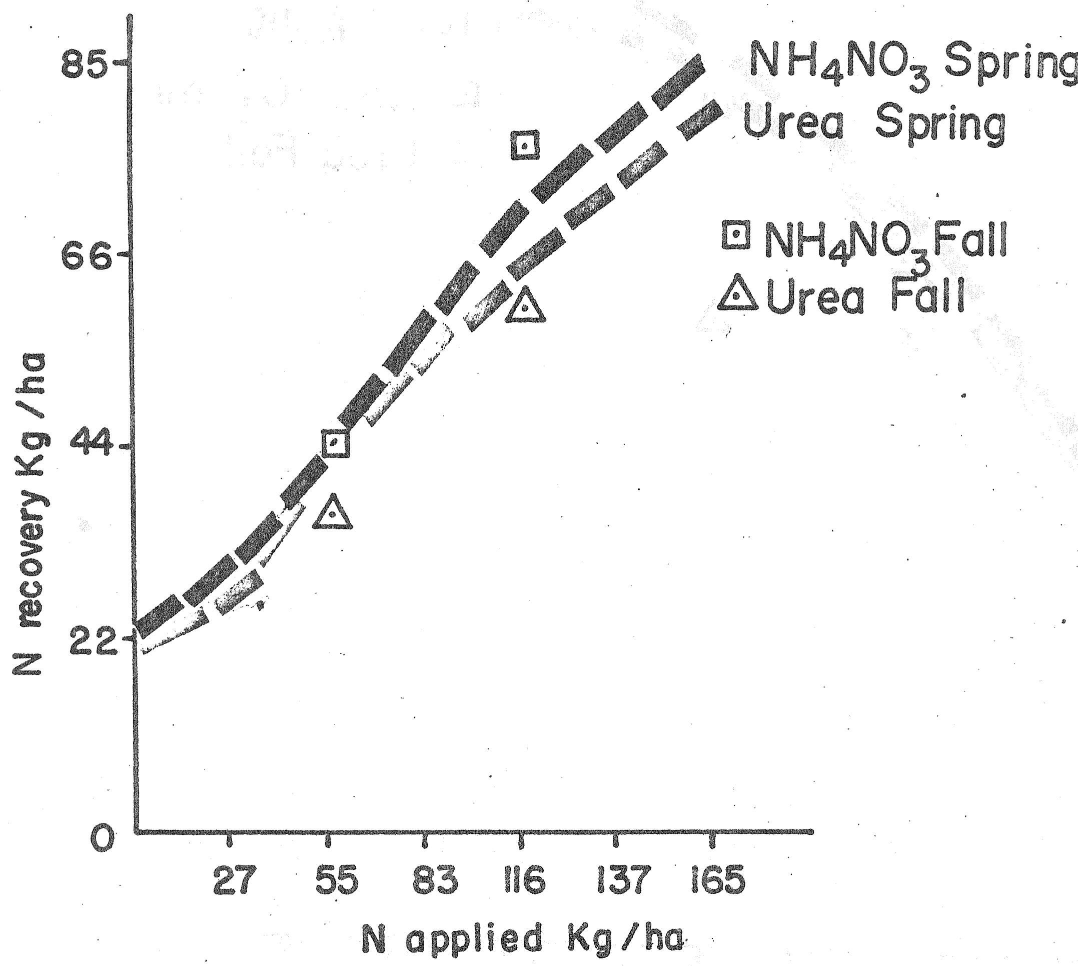
(2) Use of ^{15}N -- In 1972, the detailed experiments on the Blaine Lake soil with ^{15}N showed equal uptake of fertilizer KNO_3 and urea when applied in the spring. Fifty percent of the nitrogen was present in plant parts, 30% was present in the soil as organic nitrogen at the end of the plant growth, and 20% was lost from the system. The Carrot River soils in the microplots showed no effect of placement with plant parts containing 55-59% of the NO_3-^{15}N, soil contained 23-25% and 26% was unaccounted for (Table 1).

Table 1. Nitrogen yield and uptake parameters in 1972 barley.

		Plant parts	Soil	% recovery
		Carrot River		
KNO_3	SB	59	25	80
	Br	55	23	82
Urea	SB	40	29	69
	Br	34	33	67

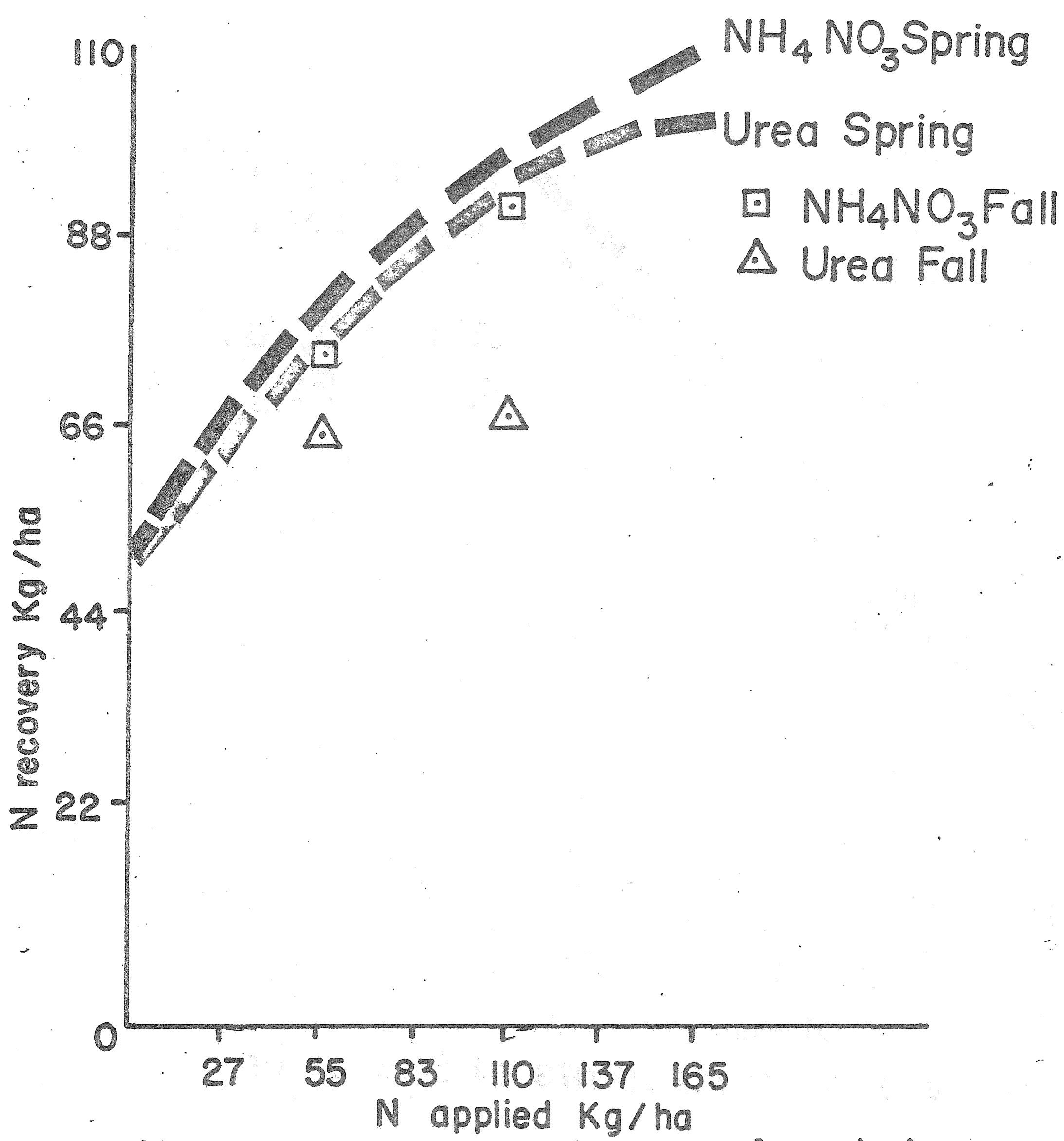
Spring application - 75 kg N/ha
SB - Side Band, Br - Broadcast

FIGURE 1



N yield on macroplots at Saskatoon

FIGURE 2



N yield on macroplots at Annaheim

Addition of urea-^{15}N showed lower plant recoveries (34-40%)and higher loss (approximately 30%). Expression of the data on a crop basis (Table 2) showed best recoveries with spring applied NO_3 added to barley and wheat. Rapeseed showed poorer recoveries of NO_3. All three crops showed limited plant recoveries of the applied urea-^{15}N with the soil containing more ^{15}N at the end of the experiment than was found in plant parts.

Table 2. Distribution of broadcast-N on two soil types (% of fertilizer N).

	Carrot River			Calcareous Dark Grey		
	KNO_3			Urea		
	Plant	Soil	% Recov.	Plant	Soil	% Recov.
Barley	55	25	80	34	33	67
Wheat	56	27	83	32	37	69
Rapeseed	38	33	71	17	50	67

Spring application - 75 kg N/ha

The use of labelled fertilizer in 1973 on a plot that was heavily infested with weeds showed no differences due to sidebanding, broadcast and seed placement. On these sites, only 20-35% of the nitrogen was found in the plant parts (Table 3). Forty to 50% was found in the soil organic matter, indicating that the weeds had immobilized much of the nitrogen making it unavailable for plant growth during that cropping year. This N remained in the soil with a total ^{15}N recovery of 64-78%. On this site, urea proved to be the most efficiently used fertilizer.

Table 3. Recovery of applied fertilizer N in crop and soil on barley plots infested with wild millet, 1973.*

Fertilizer	Plant uptake		Remaining in soil			Recovery of Fertilizer N
	Grain	Total Plant	0-15 cm	15-30 cm	Total	
	%					
NH_4	9.1	21.1	45.5	3.2	49.7	70.1
NO_3	7.8	19.3	41.6	3.1	41.1	64.0
Urea	17.1	29.0	46.3	3.2	49.6	78.4

*Blaine Lake

The ^{15}N assay on the plant parts and soil from the six 1974 experiments showed that plant utilization of fertilizer N applied either as urea or ammonium in the fall averaged 30% in contrast to 11% for the nitrate source (Table 4).

Table 4. Fertilizer N balance sheet for barley plants grown in 1974 on six different locations.

Form of N	Plant N		Soil N		Recovery	
	Fall applied	Spring applied	Fall applied	Spring applied	Fall applied	Spring applied
NH_4^+	29	28	52	44	81	72
NO_3	11	53	11	25	22	78
Urea	29	34	37	41	66	75

The nitrate source was the most effective when applied in the spring, with 53% recovery compared to approximately 30% for the other two sources. The plant uptake of nitrogen from urea or ammonia was not affected by time of application. Data obtained on the fertilizer N remaining in the soil and in the plant suggest that fall applied urea and nitrate were both subject to losses. The magnitude of the losses however were very much greater for the nitrate source for only 22% of the added N was recovered in the plants or soil. Spring applied N did not show great differences in recovery ranging from 72-78% for all fertilizer sources. It was noted that a greater proportion of fall applied urea or ammonia consistently remained in the soil and on average 25% of the nitrogen could not be accounted for and presumably was lost from the system.

Detailed laboratory experiments on the microbiology and chemistry of the different sources of nitrogen which were carried out by Dr. Dav, a post-doctorate appointee, indicate that often the lower percent recovery (uptake of urea by barley) is offset in certain soils by higher amounts of residual nitrogen in the organic form in the soil. This nitrogen should be available for cropping at future dates.

The 1975 data from ten plots indicate a higher plant uptake of spring applied N than fall applied material (Table 5). Spring NO_3-N was preferentially utilized by the plants when the NO_3-N was applied in spring. A total of 30% was found in the grain, 20% in straw plus crown and 25% in the soil for a total recovery of 75% (Table 5). Fall applied nitrate showed the greatest losses with only 37% being accounted for in the grain, straw plus crowns and soil.

Table 5. N balance sheet* for 1975 microplots (10 sites).

Treatment	Grain	Straw + Crown	Soil	Loss
Urea - Spring	18.99	12.00	32.72	38
Urea - Fall	11.59	8.32	31.72	49
NH_4 - Spring	16.99	11.35	37.25	33
NH_4 - Fall	12.33	8.24	42.86	36
NO_3 - Spring	29.25	20.57	24.69	25
NO_3 - Fall	16.00	8.16	14.71	63

*% utilization

During 1975 all fertilizers showed poor plant uptake and high losses with fall applied urea showing lower plant utilization and higher losses than fall applied NH_4. Spring applied urea and ammonia did not show any differences when the data for all ten sites were averaged.

Data for the Saskatoon site (Table 6) show results very similar to that already presented for the average of 10 sites (Table 5). Spring applied NO_3-N was most efficient as a fertilizer, whereas fall applied urea was least effective. Similar conclusions can be drawn from

Table 6. N balance sheet* for the 1975 microplots at Saskatoon.

Treatment	Grain	Straw + Crown	Soil	Loss
Urea - Spring	20.45	16.55	39.01	23.99
Urea - Fall	7.79	9.58	37.38	45.25
NH_4 - Spring	15.70	12.79	46.26	25.25
NH_4 - Fall	12.64	11.59	49.36	26.41
NO_3 - Spring	27.28	18.73	24.33	29.66
NO_3 - Fall	19.26	7.77	7.72	65.26

*% utilization

the specific data for the Annaheim site (Table 7). Again spring applied NO_3 was most effective and generally spring application was superior to fall application for all fertilizers.

Table 7. N balance sheet* for the 1975 microplots at Annaheim.

Treatment	Grain	Straw + Crown	Soil	Loss
Urea - Spring	16.19	10.70	21.61	51.49
Urea - Fall	10.26	6.21	29.21	54.35
NH_4 - Spring	15.64	7.98	26.82	49.55
NH_4 - Fall	11.37	7.40	35.77	45.45
NO_3 - Spring	41.34	22.25	18.09	18.31
NO_3 - Fall	12.53	8.12	11.46	67.88

*% utilization

Conclusions

We have shown that urea does not have in general a disadvantage when compared to ammonium nitrate when applied under fall conditions. However, the NO_3 ion is selectively utilized to a greater extent than the NH_4 (Table 7). Any fall applications of fertilizer must be approached with great caution, for this is the time when great losses can occur especially if large amounts of NO_3 are present.

On the plots where urea or NH_4^+ showed poor plant uptake, the labelled fertilizer was often found present as residual nitrogen within the soil system. Table 8 shows that the highest soil N values were found where

Table 8. % recovery of ^{15}N in soil (data from ten 1975 microplots).

Group*		Mean
	Subset 1	
NO_3 - Fall		14.7
	Subset 2	
NO_3 - Spring		24.7
	Subset 3	
Urea - Fall		31.7
Urea - Spring		32.7
NH_4 - Spring		37.3
	Subset 4	
NH_4 - Spring		37.3
NH_4 - Fall		42.9

*Group differentiated at 0.010 level

$^{15}NH_4$ was applied with an average of 40% of this nitrogen being found as residual N. Urea showed slightly lower soil N values and NO_3 especially if fall applied resulted in very much lower soil N contents. The summary statistics for recovery of N in the grain (Table 9) show that all fertilizers gave low recoveries when fall applied and NO_3 was most efficient in spring. Continued use of urea or NH_4^+ should lead to the build-up of available soil nitrogen reserves for the future. The high level of incorporation of ^{15}N into the soil is thought to be primarily into organic forms of N but fixed NH_4^+ may also be involved.

Table 9. % recovery of ^{15}N in grain (data from ten 1975 microplots.

Group*		Mean
	Subset 1	
Urea - Fall		11.4
NH_4 - Fall		12.3
NO_3 - Fall		15.1
	Subset 2	
NO_3 - Fall		15.1
NH_4 - Spring		17.0
Urea - Spring		18.6
	Subset 3	
NO_3 - Spring		29.3

*Group differentiated at 0.010 level

The high levels of nitrate movement as measured by ^{15}N under fall conditions further lead us to question the general summerfallowing practices. There is no reason why fertilizer nitrogen should behave differently than soil nitrate nitrogen. The extensive data we have obtained to date, therefore, also indicate that the present summer-fallowing practices can lead to very poor nitrogen conservation. Continuous cropping with an adequate fertilizer program would lead not only to a retention of soil organic matter levels but also a prevention of nitrate nitrogen moving into the ground water and surface lakes.